WORKING PAPER
ALFRED P. SLOAN SCHOOL OF MANAGEMENT

ORGANIZATION RESEARCH PROGRAM

CPIF: The New Look in R and D Management

Charles H. Greer
Associate, McKinsey & Company, Inc.

May, 1964 #65-64

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS, 02139

ORGANIZATION RESEARCH PROGRAM

CPIF: The New Look in R and D Management

Charles H. Greer
Associate, McKinsey & Company, Inc.

May, 1964 #65-64

From Industrial Management Review, 1964, 5, 87-96. The paper was originally prepared in May, 1963 for Professor Donald Marquis's course in Management of Research and Development at the Sloan School of Management.

CPIF: The New Look in R and D Management

Charles H. Greer
McKinsey and Co., Inc.

The customer purchasing a newly developed weapon or aerospace system expects to pay for an end product which fulfills significantly advanced performance specifications, is available on time, and costs no more than has been planned and funded. In general, the customer is a military or quasi-military agency of the Federal Government, but may also be a subcontracting industrial supplier, who in turn is supplying a customer with the same expectations.

The contractor supplying the newly developed system expects to obtain a reasonable return from his investment in the contract, that is, compensation sufficient to cover his costs and provide a profit.

A discussion of the systems contracting process cannot be undertaken without consideration of the difficulties inherently involved.[1] The uncertainties and risks involved in the projects, the difficulty of determining the scope of the projects and the standards by which progress may be measured, the high mortality rate which prevails and the costs incurred by both customer and supplier upon cancellation, the long planning and development lead times, the rapidly shifting requirements which are exogenously imposed upon customer planning, and the major uncertainties relative to proper project management—all act to prevent the customer or supplier, or both, from obtaining a satisfactory outcome.

Into this interplay of customer goals, supplier expectations, and inherent environmental factors has been thrust the necessity for establishing contracting procedures by whose terms each project may be undertaken and monitored. It is this contracting procedure which will be examined.

Experiences Under CPFF

The CPFF (Cost Plus Fixed Fee) contract has traditionally been empolyed for development projects when accurate pricing could not be determined, that is, when the difficulties noted above were so great as to preclude accurately estimating the resource investment which would be required and the problems which would be faced. As such projects have become more common, the use of CPFF contracting procedures has grown. During the decade between 1951 and 1961, CPFF contracts tripled from 13% to 39% of the DOD dollars spent; the dollar volume growth has more than tripled, of course.[2]

From the point of view of the aerospace and defense industry, CPFF contracts have simultaneously become the largest headache and the lifeblood of the greater portion of private firms engaged in governmental R and D. The return on sales volume from CPFF contracts is quite low; most firms engaged primarily in CPFF work make a 3% return their goal.[3] As the number of such contracts decreases and the average size grows, this situation will deteriorate even further. It is necessary to keep weaker firms alive to maintain the industry's capacity and to prevent the blight of regional unemployment from spreading; this means that the smaller number of contracts will be spread thinly and the large size of each contract will require the chosen firm to staff up far beyond average workload require-

[1] Roberts, [1], pp. 1-4; Peck and Scherer, [2], pp. 17-31, 299-323.

[2] [3], p. 2; Peck and Scherer, *op. cit.*, p. 100.

[3] Peck and Scherer, *op. cit.*, pp. 207-213.

ments in order to meet peak needs. It is clear that the primary motivation of the suppliers will become survival—the stretching out of, and loading onto, such contracts as are in the house to pay for the crushing overhead which must be carried until the next big CPFF billpayer comes along.

From the points of view of the Department of Defense and National Aeronautics and Space Administration, the present situation is no more satisfactory. The problems inherent in planning and procuring today for the needs of six to eight years hence are great enough without the added burdens of lagging program schedules, technical failures, and massive, budget-shattering cost overruns. There is little question that the customer is not getting the end products wanted, when planned, at the cost predicted; instances of misestimation and mismanagement are only too well publicized.[4]

These instances and the averages which reflect the poor level of performance are partially the result of the inherent problems of R and D contracting and procurement. But the motivations arising from the CPFF contracting process are clearly contributory. To the extent that fee is unrelated to performance, cost, or schedule maintenance, to the extent that the assumption of a CPFF contract becomes virtually riskless, and to the extent that the reward of production follow-on shrinks as end products become one of a kind or at most ten or fifteen, the major incentive will be for the contractor to milk each contract for as much as possible, while using the opportunity to build skills (and prepare proposals) which will lead to the next contract.

The Department of Defense under Robert S. McNamara has recognized these problems. In response, the DOD has begun to introduce new techniques for program definition, selective procurement, and closer, more accurate monitering of technical progress, schedule maintenance, and cost control. Coupled with these measures is an increasing emphasis upon the use of a contracting process which reestablishes the proper motivations for defense and aerospace contracters—the CPIF contract.

[4]*Ibid.*, pp. 428-451; Roberts, *op. cit.*, pp. 3-4.

Philosophy of CPIF

Cost Plus Incentive Fee (CPIF) contracts have had a long history in defense procurement. In 1908, for example, the Signal Corps bought a "flying machine" under a contract which set a target speed of 40 m.p.h. and agreed that the contract target price would increase or decrease 40% for each increase or decrease of 4 m.p.h. above or below target speed.[5] In general, the recent use of incentive fee contracts has been limited to production contracts only, with a fee contingent upon cost alone.

The philosophy behind an attempt to establish similar incentives for end-item performance and schedule maintenance is quite simple: to the degree to which compensation can be related to project performance, contractors will be motivated to control costs, maintain schedules, and promote technical excellence. Further, compensation should be so determined for the benefit of the nation, the Department of Defense and N.A.S.A., and ultimately, the individual contractors. Those contractors who perform comparatively well, i.e., set realistic goals and meet or exceed the goals set, should be compensated accordingly. Those who do not should be penalized. The application of such a plan should lead not only to better project performance, but also to the ability to depend upon the estimates of those contractors who are proven to be realistic goal setters. Hopefully, much of the uncertainty "inherent" in R and D planning could thereby be eliminated.

It is clear that the Defense Department intends to use CPIF wherever possible. N.A.S.A. is expected to follow suit. The Grumman A2F contract may have seemed only a straw in the wind, but the now-famous TFX procurement demonstrates that the government intends to view development as a predictable, manageable process amenable to *a priori* estimation and during-the-fact control.[6] Both the government and industry can benefit; those contractors who understand the process of managing CPIF contracts and act accordingly will find the greatest rewards obtainable.

[5][3], p. 1.

[6]Smith, [4].

How CPIF Works[7]

Construction or establishment of a CPIF contract is basically a four-step task. Since the fee structure will be composed of three elements, the relative weight of each element becomes crucial. Hopefully, the weighting will serve to reflect the customer's desires and his conception of the uses to which the basic end-product will be put. If this is the case, the contractor faced with a decision will be motivated to choose that path which reflects the best interests of the customer. Weighting also can adapt the basic contracting technique to diverse project and end-product requirements. For example, in the initial stages of a non-strategic procurement, weighting based primarily upon end-item performance and only secondarily upon schedule maintenance and cost control might be appropriate: performance—60%, time—30%, cost—10% weighting. The early stages of a vitally strategic weapons system cycle might be marked by a performance—25%, time—70%, cost—5% allocation. Finally, a basic production contract might weight only cost, and set go/no go criteria for schedule and performance provisions. This would approach a fixed price contract.

The second step in the establishment of a CPIF contract is determination of those elements of end-item performance and scheduled progress which can serve as measurable targets for incentivization. Care must be applied to ensure that the elements chosen are precisely measurable, that they are independent and discrete and therefore not contradictory, that a reasonable number are selected, and that they are balanced so that one does not "dominate" the solution chosen by the contractor.

Once the elements of performance and progress are chosen, goals or targets are set against which project performance will be measured. Target setting is initially a competitive process, using the familiar proposal scheme. Strategy and incentives become quite different, however; since one is measured against the promises one makes, each estimate must not only be sufficiently sanguine to win the contract, it must also be pessimistic enough so that reasonable performance becomes possible. In the general case, the required estimates or targets are of three classes: cost, schedule, and end-item performance. It is possible that in many cases target setting may be by negotiation with the customer, rather than strictly through competitive proposals. This would be analogous to the present sole-source placement of many CPFF contracts.[8]

After the targets are set, the relationship of the fee structure to each targeted characteristic must be established, again either through competitive proposals or negotiation. This involves a decision as to the percentage of basic fee which depends upon the cost or schedule or end-item performance, followed by a determination of the "saving" in fee segment as a function of exceeding or falling short of the applicable target. This step will be discussed in detail later in this paper.

By law, the CPIF contract is limited to a maximum possible incentive fee of 15% of the target cost of the contract; in addition, each CPIF contract must have a stated minimum and maximum fee. The minimum will ordinarily be at least sufficient to prevent actual contractor out-of-pocket loss, although a negative fee is not unthinkable. Of course, it is expected that the bulk of the cost of a CPIF contract, the costs of contract performance exclusive of fee, will be repaid regardless of project performance.

The final step in the contracting process is the specification of the relationship of fee to under- or over-performance in each of the three basic target areas: cost, schedule, and performance. This stage is described below in the context of each of the three basic incentive areas.

Cost Incentives

Contracts containing straight cost incentives alone are, and have been, widely used. The degenerate case in this class is the fixed price contract, in which the contractor gains or loses 100% in over- or under-performance. Conceptually, the cost incentive

[7]See [3] for an excellent, complete and definitive discussion of the CPIF contract structure. This section is drawn primarily from this publication.

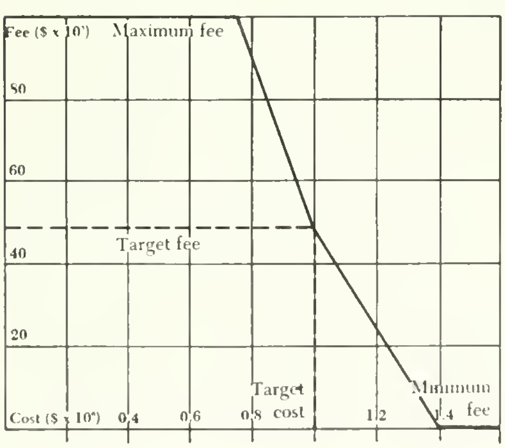
[8]See Peck and Scherer, *op. cit.*, pp. 324-385, for a complete discussion of the processes by which contracts have been placed in the past.

provision is the most easily defined. A total target cost figure is established for the contract, exclusive of fees. Regardless of the final audited cost, the contractor is guaranteed he will recover his outlay. However, his fee will be increased (or decreased) from the target fee by a percentage of the amount by which the actual cost falls short of (or exceeds) the cost target.

This is not to imply that the establishment of the cost-fee relationship is a simple matter. Several points must be considered. First, the customer cannot expect the supplier to assume the infinite risk implied by not setting a minimum fee. Thus, a cost point must be reached beyond which the customer agrees to assume all costs if he desires work to continue. Second, there is some cost point below which the fee cannot continue to grow, since by law fees are limited to 15% of target costs. This same legislation also demands the setting of a target cost (obviously between the costs corresponding to the maximum and minimum fee points). It is at this target cost that the target fee (rather, that the portion which is dependent upon project cost) is to be awarded. These three figures: target cost, minimum fee cost, and maximum fee cost, along with the chosen target, and maximum and minimum fees, form the starting points for one method of establishing the fee-cost relationship.

An example is given below. Assume a target cost of $1,000,000 and a target fee

Figure 1 Example of CPIF Cost/Fee Structure



of $50,000. Further assume a maximum fee of $100,000 and a minimum of $0, to be obtained at costs of $750,000 and $1,400,000, respectively. Figure 1 illustrates the resultant sharing relationship. Above the target cost, the customer pays 87.5% of all additional dollars spent, the supplier 12.5% —an 87.5-12.5 share line. Below target cost, the share line is 80-20.

Clearly the setting of each element contained in this diagram merits considerable discussion. Our purpose here, however, is merely to illustrate the way in which one portion of the total fee depends upon the project cost. It should be sufficient to note that the share lines need not be straight (a fixed percentage return for dollars saved), the spread above and below target cost (or target fee) need not be equal, and that the cost-related fee can be any fraction of the total fee between 0% and 100%. The degree of flexibility available and the motivations which may result, need to be investigated carefully before such a task is undertaken.

Schedule Incentives

The establishment of a schedule-fee relationship is somewhat more subtle and complex than a cost-fee relationship. Dollars provide a ready-made measure of "performance;" time is not necessarily a straightforward concept. What is to be incentivized, the final completion date or each significant milestone along the way upon which other programs and procurements depend? If only the final delivery of a completed end-item is important, how is the establishment of one incentive date to ensure control throughout the life of the project (without which, presumably, the probability of meeting the final date becomes very small)?

If the schedule-fee relationship depends upon more than a single date, the complexity of the situation becomes apparent. Significantly, the use of multiple schedule targets coincides with the current Department of Defense/N.A.S.A. emphasis upon PERT or PERT/COST analysis; it would not be untoward of the customer to require either PERT/COST or PERT and to incentivize the meeting or slippage of each truly significant and easily measured event.

The introduction of several schedule ob-

jectives raises the problem of relative weights among the alternatives. In general, it would seem that the objectives should assume greater weight as the end of the project is reached; this seems to be the trend, as exemplified by a recent military solicitation:[9]

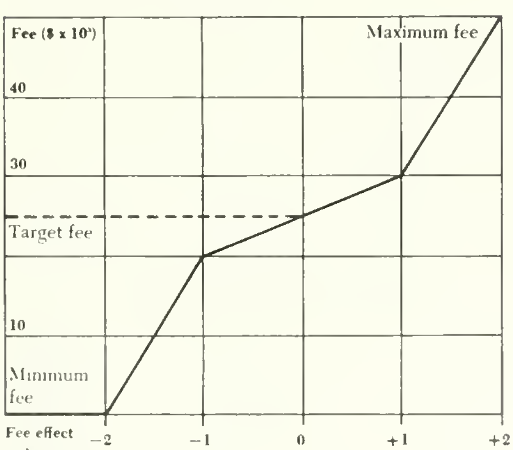
	Item	Weight
1.	Complete Program Plan	0.5
2.	Design Evaluation	0.5
3.	Fire First Complete Motor	0.5
4.	Begin Pre-Flight Rating Test	0.5
5.	Complete Pre-Flight Rating Test	1.0
6.	Deliver First Flight Test Motor	1.0

A total of four points was possible, which in turn were related to the impact upon the fee:

Score	Free effect scale
3.6-4.0	+2
3.1-3.6	+1
2.1-3.0	0
1.0-2.0	—1
0.0-0.9	—2

In this scheme, each objective was a hit-or-miss matter, so no question of "missed by how much" was relevant; clearly a sliding scale to modify the influence of a miss could be designed. The fee effect scale (or the "raw score") could then be related graphically to the fee in a manner similar to that illustrated in Figure 2:

Figure 2 Example of CPIF Schedule/Fee Structure



[9][3], p. 29.

Again, it is pertinent to note that this relationship has all the flexibility (and consequent complex potential motivating power) found in the cost-fee relationship.

End-Item Performance Incentives

The most complex problems reside in the specification of the relationship between the fee and the several significant parameters of end-item performance. To the extent that the proposed development approaches or surpasses the state of the art, these problems become more important.

A performance incentive may be established in a manner similar to the cost and schedule incentives. First, the performance areas of special significance to the customer are selected. Next, these areas are weighted to reflect their relative importance. Third, clear and measurable targets are established such that skillful performance can attain them, superior performance can surpass them, and poor performance will fail to attain them. Finally, the impact of failing to achieve a target, or of exceeding it, must be specified in detail so that the end-item performance fee can be computed.

It may be necessary, in those important areas in which quantitative measurement is not feasible, to establish a subjective method of measurement. It is not inconceivable that a board of independent scientists be established for each project to examine complex technical achievements and award points toward a fee goal. This system is, of course, less preferable than the more definitive measurement technique, but it may be required in some cases.

An example will illustrate how the performance incentive might work.[10] Assume the important technical parameters selected for a ground-to-ground missile system are: range, accuracy, speed, and reliability. These are to be weighted (based upon customer requirements):

Range	20%
Accuracy	40%
Speed	10%
Reliability	30%

[10]Another similar example may be found in [3], pp. 34-35.

Table 1 Performance Incentive Fee Based on Technical Performance

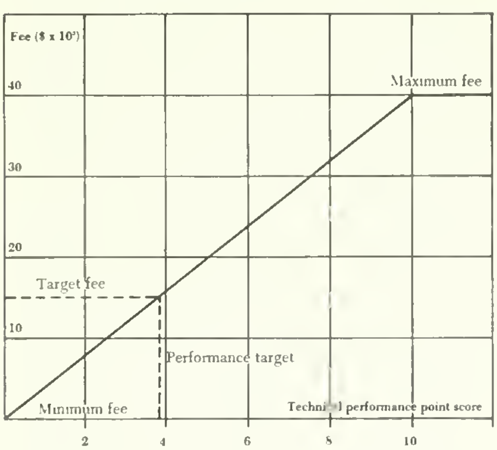
Parameter	Target	Target fee	Max/Min fee	Performance/Fee relationship
Range	5000 mi	\$3000	\$8000/0	\$1000/200 mi.
Accuracy	2.0 mi.	\$6000	\$16000/0	\$1000/0.2 mi.
Speed	15,000 m.p.h.	\$1500	\$4000/0	\$500/1000 m.p.h.
Reliability	95%	\$4500	\$1200/0	\$1500/1%

The total maximum fee based upon technical performance might be set at \$40,000 and the minimum at \$0; the target fee might be established at \$15,000. The appropriate relationships are established in Table 1.

Alternately, a performance point score might be established as shown in Table 2. This would lead to a total point score (which could be positive or negative), and a fee/score relationship could be specified as in Figure 3:

Again, one must recognize that a great deal of flexibility is possible in establishing the performance/fee relationship. Great care must be taken to ensure that the structure which is chosen does, in fact, motivate the contractor to perform as the customer desires.

Figure 3 Example of CPIF Performance/Fee Structure



Multiple Incentives

The relationships which we have discussed have been complex; the problems which arise when one attempts to specify all three relationships acting in concert, for a real contract, when questions of "who will measure which variables and when" must be solved, are immense. Estimation of the motivations which may exist is an extremely subtle judgment; since each of the factors is, to some extent, related to all the others, the fee/performance relationship designer must be extremely careful not to design a structure in which any one or two considerations outweigh all others, or in which some of the incentives do not seem to have any actual incentive value. The aim must be to create an environment in which the contractor will be motivated to produce a satisfactory end-item, on time and on dollars, with a balance among these three factors which reflects the customer's needs and desires. With a virtually infinite number of degrees of freedom, it would seem to be extremely difficult to establish such a contract structure; however, the possibility of so doing is clearly present.

No less complex than the task of proposing or negotiating such a structure is that of managing a project within the resultant environment. The decisions which

Table 2 A Performance Point Score

Parameter	Target	Weight	Performance/Fee relationship
Range	5000 mi.	2.0	(Range—4400)/800 ($X \leq 2$)
Accuracy	2.0 mi.	4.0	(3.2—Accuracy)/0.8 ($X \leq 4$)
Speed	15,000 m.p.h.	1.0	(Speed—12000)/8000 ($X \leq 1$)
Reliability	95%	3.0	(Reliability—92%)/2.67 ($X \leq 3$)

must be made, strategic and tactical, before the fact and during performance, are far from trivial. It is to these decisions that the contemporary defense or aerospace contractor must address himself.

The Management of CPIF Contracts

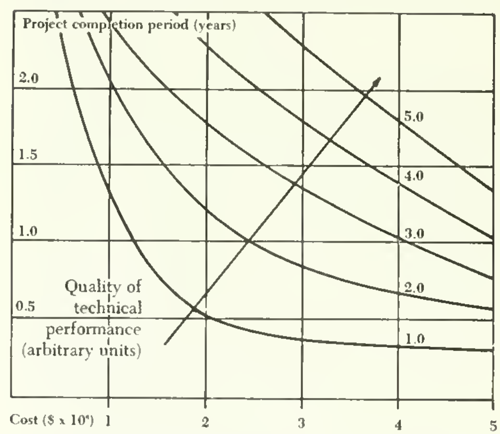
A common finding among observers of the research and development scene is that very little seems to be known about how to manage effectively in an environment containing the problems described in the first section of this paper. It has become apparent, however, that in an environment within which a contractor is not penalized for slipping schedules, overrunning costs, nor for producing substandard items, little effort will be expended upon discovering how to prevent such occurrences. Rather, the bulk of effort seems to have been concentrated upon marketing and brochuresmanship tasks in order to ensure survival in the non-market structure of government R and D contracting.

It is equally clear that should the DOD and NASA increase their emphasis upon CPIF—and all indications point to this—the problems of project management could not be ignored in favor of marketing efforts. In fact, the problems of project management, which in the past have been only obliquely faced by contracting organizations, will become directly relevant to corporate survival. Decisions relating to tradeoffs between performance and costs, or costs and schedule, for example, will no longer be permitted to "work themselves out" or to be decided casually. Each such decision will have a direct and determinable impact upon corporate profits. Evidently, the problems of project management will be increased, crystallized, and imbued with an enhanced relevance.

The Essential Problem

It may be assumed that, in general, each of the incentive elements of a multiple CPIF contract is related to all of the other elements. Cost may not be reduced without affecting the schedule and the end-item performance parameters; increased technical performance can be gained only through either increased cost, or time, or both. With these assumptions, the problem before and during the fact is that of choosing the point in an n-dimensional project performance space at which one wishes to operate in order to maximize the sum of contribution to fixed corporate overhead and project fee. Consider the simplified case illustrated in Figure 4.[11] The interrelationship among the three dimensions uniquely specified by this diagram is pictured. Associated with each of the infinite performance points within the space is a figure which represents the sum of project fee plus contribution to fixed overhead. It is a pragmatically simple matter to select, through trial and error, (although no optimization technique, short of dynamic programming, exists which can do so) that performance point which will maximize the corporate return.

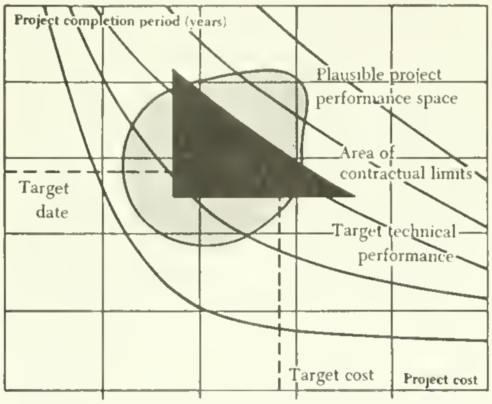
Figure 4 Example of Project Performance Space



Superimposed upon this actual (but unknown) possibility space are the contractual terms, which include targets, fees, and performance/fee relationships. With respect to the surface or n-dimensional volume pictured, these terms will probably be nonlinear. Each dimension, however, will have a limiting point beyond which added increments will not provide a return to the corporation, and another point below which fee will not be further reduced. Thus, as shown in Figure 5, an area of interest is sliced from the project performance space within the plausible performance bounds:

[11]This construct was first published in Peck and Scherer, *op. cit.*, pp. 255-274.

Figure 5 Example of Project Performance Space with CAF Contractual Limits



In even this simplified case, the problem is at least four-dimensional: cost, schedule, end-item performance, and fee plus contribution to fixed overhead (the criteria surface). The problem faced by the supplier is to choose his performance point in a nonlinear four-dimensional space, without the aid of any analytic tools to guide his decision. Three considerations multiply the difficulty of his task by an order of magnitude.

First, in all likelihood the schedule dimension has at least three or four subdimensions which are related in a nonlinear fashion with each other and with all other elements of the fee structure. The same complexity may be found in the technical performance dimension, which in an actual case may consist of four or five subdimensions related nonlinearly to all of the elements of the performance space. Thus, an actual case may exist in a nine, ten, or eleven-dimensional nonlinear project performance space.

Second, the neatly specified relationships pictured in Figures 4 and 5 may actually exist, but they are, in fact, not known precisely by the customer or the supplier. Further, the customer and the supplier may have entirely different preconceptions as to the structure of this approximately ten-dimensional performance possibility space. Thus, the supplier is forced to negotiate, contract, and manage in a nonlinear, multidimensional environment of whose structure he has only the foggiest estimate.

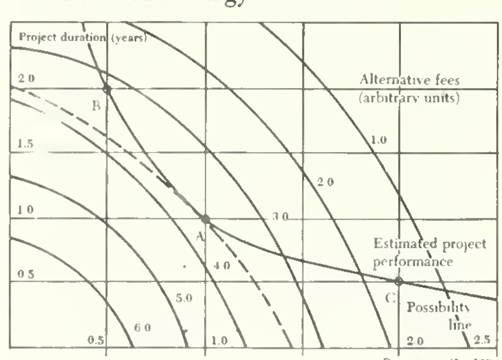
Third, as the project progresses, the contractor's conception of the structure of his environment—his estimate of what he can do—will change. Decisions which seemed "good" before now are revealed to be suboptimal; choices which were eliminated are seen now to be desirable. Further, it may not be possible to move toward a choice now revealed as optimal, since the costs of shifting strategies may preclude a reevaluation. Thus, the proper strategy may have been to gather all the fees in low cost, and to let the schedule slip. By the time the contractor's error in shooting for an early completion by ignoring costs is revealed, costs may have grown beyond the point at which any incentive fee can be gained. The project manager has, in effect, become more and more married to the strategy he has chosen; right or wrong.

There is little question that project management within such an environment is one of the most difficult tasks faced by contemporary industrial society.

The Strategy of Performance

The process of project management, as it has been analyzed above, appears to be extremely complex. By making appropriate assumptions, however, it is possible to sketch an optimal strategy of project performance under a CPIF contract. Consider Figure 6 (which has only two dimensions of project performance for the sake of clarity) as an example which, although greatly simplified, contains all of the conceptual problems found in a real case. Note that only schedule and cost considerations enter here. The curve which is convex toward the origin contains all possible optimal combinations of time and money which

Figure 6 Example of Project Performance Strategy



will produce the desired end-product. The curves concave toward the origin represent the fee structure—the gains which will result should the desired product be produced with given combinations of time and money.

Ignoring, for this example, the possibility of an irreplaceable contribution to fixed overhead, the firm's objective is merely to determine the point at which the fee is maximized (Point A) and then to manage the project so that the end-item is produced for $1,000,000 in 1 year instead of for $2,000,000 in ½ year or for $500,000 in 2 years.

Given the fee structure as shown and the project performance space illustrated, Point A may be found through trial and error. In a more realistic problem (say with ten-dimensional, nonlinear relationships) this would be quite difficult, so an analytic technique would be necessary. With appropriate approximations linear programming could be used; of course the relationships are rarely linear so nonlinear programming[12] might be more useful, but simplifying assumptions would still be necessary. Dynamic programming[13] seems to offer a more exact solution if only the relationships can be specified accurately. Possibly simulation would be helpful, since small errors are not significant.

Theoretically, this problem is now solved. All that remains is the inclusion of a few perfunctory remarks about error sensitivity, the possible practical problems which might be found, the need for careful *a priori* estimation and, subsequent to the selection of a strategy, careful management control to ensure that the strategy is followed.

Unfortunately, this theoretical construction is of no practical value whatsoever, given the present day state of the art of project management. The reasons why this is so are quite obvious to anyone who has ever managed an actual research and/or development project. First, the contractor —and the customer—have only the vaguest of notions of the actual relationships among the dimensions of the project performance space; as history has shown, these notions may be in error by as much as a factor of ten.[14] Although the CPIF contract may specify the project performance/fee relationships with sufficient accuracy, it is useless to attempt to compare these definitive relationships with the fuzzy guesses about what can be done for X dollars in Y years, what the tradeoffs are between range and weight, or between dollars and years, or between reliability and schedule. From the contractor's point of view, the carefully developed fee/project performance structure is built upon a foundation of sand.

Second, even if the project manager knew exactly what his optimal strategy were to be, he still would be faced with the problem of carrying out the plan during the course of the project. This, in turn, would require that he have the ability to determine where the project stands, i.e., what progress has been made, and to influence progress in a significant and predictable manner should it be necessary. A good deal of evidence has been gathered[15] which indicates that, although elapsed time is easily measured and expended funds may be known, the measurement of technical progress (without which knowledge the other two pieces of information are worthless) is extremely difficult.

It is evident that the use of the CPIF contracting process will motivate better contractor performance. It is also clear that such use merely will intensify the problems faced by project managers; it seems doubtful that any relief will be forthcoming in the near future from such attempts at strategy planning (or "optimizing") as were described above. The transition from the theoretical to the practical is just too difficult. Nonetheless, an analysis such as has been presented above is of value. Through the process of examining the theoretical problem and its solution, and attempting to specify how such a solution would be implemented, the practical barriers to effective project management are pinpointed. This can then lead to statements about the real needs of project management, upon

---

[12]Wolfe, [5], pp. 438-447.

[13]Bellman, [6], contains some applications examples which are similar to this problem.

[14]Peck and Scherer, *op. cit.*, pp. 22-25.

[15]*Ibid.*, pp. 309-314.

which effort should be concentrated.

Implications for Project Management

Cost Plus Incentive Fee contracts are becoming the rule rather than the exception in military research and development. The use of CPIF is predicated upon a reestablishment of the proper motivations for defense and aerospace contractors—incentives lacking in the traditional CPFF contracting process. These incentives will place a greater portion of the risks inherent in R and D upon the contractor, requiring an even greater concern for the problems of project management. CPIF contracts, which specify precisely the returns from development tradeoffs, provide an important field for the efforts of operations researchers; such efforts will be hindered by the practical problems of strategy formulation and implementation. It is clear that the usefulness of such techniques depends upon the development of: the ability to estimate the relationships among the possibly ten or more dimensions of the project performance space (these relationships are highly interdependent, complex and nonlinear); the ability to select a project performance objective—a strategy of management aimed at a particular point in the project performance space—which maximizes the contractor's fee plus the contribution to fixed costs; and the ability to influence, significantly and predictably, the course of the project in order to achieve the chosen endpoint.

The accuracy of the supplier's estimate of the dimensional relationships is a function of his experience and background in the particular project area. This implies that, more than ever before, it will be necessary to expend a great deal of pre-proposal effort, funded by supplier capital, in the project area. The ability to select a project performance objective, a strategy of project management, is already within the reach of operations research—if the performance space relationship estimates are available. This step depends upon the development of the first skill mentioned.

Improved project management, that is, the ability to guide progress toward the chosen goal, must await the development of (1) a technique for measuring continuously and accurately the investment of time and money resources *and* the technical progress which has been achieved, and (2) the ability to reallocate resources, to reorganize, and to make rational tradeoffs so that the gap between actual and desired progress is continuously being narrowed.

The thoughtful reader may well comment that these several requirements are not new. Effective project management has always had these needs; the introduction of the CPIF contracting process merely accentuates the deficiencies which exist. One can hope, however, that the establishment of strong motivations for solution, as CPFF contracts could never do, will lead to improved project management.

References

1 Roberts, E. B., *The Dynamics of Research and Development,* (unpublished PhD dissertation) Cambridge, Mass. Department of Economics, M.I.T.

2 Peck, M. J. and F. M. Scherer, *The Weapons Acquisition Process: An Economic Analysis,* Cambridge, Mass., Harvard Graduate School of Business Administration, 1962, pp. 17-31, 299-323.

3 *Incentive Contracting Seminar,* Boston, Mass., Harbridge House, Inc., 1962.

4 Smith, R. A., "The $7-Billion Contract that Changed the Rules," *Fortune,* Vol. LXVII, No. 3, 4, 1963.

5 Wolfe, P., "Some Simplex-Like Nonlinear Programming Procedures," *Operations Research,* Vol. 10, No. 4.

6 Bellman, R., *Dynamic Programming,* Princeton, N. J., Princeton University Press.

Charles H. Greer, S.M., *Associate, McKinsey and Co., Inc., New York.* Consultant in management uses of computers and management of research and development.